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Project Pre-Proposal: Using Python and OpenGL to Model Vortices

For a little background about myself, I am currently a junior in mechanical engineering. This semester I am conducting undergraduate research that has to do with fluid mechanics, specifically with wind turbines and the addition of winglets to the ends of the blades, and I am also taking a fluid mechanics class, ME 310. Because of these two things, I have fluid mechanics on the mind, and when I was searching for a project idea, my ideas instantly gravitated towards something related to my research and the courses that I am currently taking.

The main focus of my research is the formation of vortices at the tips of turbine blades and the effects that this has on the rotation of the blades. Basically, the formation of these vortices occurs at the tips when the flow along the span of the wing interferes with the flow along the cross section of the wing. The formation of these vortices induces drag on the turbine blades. If it were a plane, the plane would have to increase its angle of attack, the angle between the oncoming flow of air and a reference line on the wing. Since we are dealing with the wind turbines, however, one cannot simply adjust the angle of attack on the fly, and the induced drag reduced the power output of the turbine and makes it less efficient.

One way to mitigate the issues created by these vortices is to add winglets to the tips of the turbine blades. Numerous studies conducted have indicated that the addition of a winglet will reduce the induced drag by "moving" the vortices away from the wings or the turbine blades. This results in increased fuel efficiency in the case of planes or in a greater coefficient of power in the case of turbine blades, both of which are very good things. My research deals with investigating this phenomenon more in-depth, and potentially optimizing the design, placement, and orientation of the winglets such that power can be maximized while minimizing the new forces and moment acting on the turbine blades.

Figure 1: Vortices produced from turbines on large wind farm. Credit: http://www.reed.edu/beyond-reed/worksdays/assets/images/2014/09/Nick%203-1%20Wind%20Turbines.png

With this background, my project for this class finally becomes relevant. I wish to somehow model the vortices that occur at the wing tips. My first idea was that the vortex size, shape, and location would vary with the geometry of the wing; however, I feel like if I were to do this I would be creating my own computational fluid dynamics software, something that I am not nearly skilled enough to do. We can turn that into a ridiculous stretch goal, but it certainly can't be the primary aim of the project. My second idea was simply to model the vortices themselves. I can use the governing equations for the shape and intensity of the vortices and then convert these equations to code using Python and OpenGL. My third idea was to get away from the vortices altogether and model the turbine itself using a 3D modeling framework and Python, not necessarily OpenGL. A fourth, auxiliary idea that can apply to any of the previous ideas it to allow for user input through JavaScript and have that code interface with the Python from the actual modeling portion of the code.

Considering these ideas, idea number one will become a stretch goal for the rest of the project. Perhaps, for the second and third ideas, they can be synthesized but not necessarily dependent upon one another. What I mean by this is that the turbines and the vortices can be modeled independently, but that the vortices can be made to appear at the tips of the turbine blades. This will give it the illusion that they are dependent upon one another without me having to create my own CFD software. I could then apply the fourth idea, and take user input on the design of the turbine blades and the size of the vortices.

One thing that I think would be very interesting to do is have a variable "wind speed" that could be modeled by lines of varying length. The speed of the turbine and the size of the vortices would then vary with the wind speed. This is something that will likely be a part of the equations for the vortices at the very least, but I think it would be interesting to visualize the relationship between the wind speed and the vortices.

Thus, I believe that my final project will be to model a rotating wind turbine, "attach" vortices to the tips of the turbine blades, and allow user input to control the appearance of those two things. Modeling itself will occur using Python and OpenGL and user input will be managed using JavaScript, as I don't believe I know enough JavaScript to do much more than that. It should be an excellent learning experience with both Python and JavaScript, and I hope that I can proceed with this project.